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STRUCTURAL FACTORS RESPONSIBLE FOR THE SELECTIVITY OF THE ADSORPTION MECHANISM PRODUCING A LOSS OF STRENGTH IN METALS

V.M. Zalkin

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STRUCTURAL FACTORS RESPONSIBLE FOR THE SELECTIVITY OF THE ADSORPTION MECHANISM PRODUCING A LOSS OF STRENGTH IN METALS

V. M Zalkin†

ABSTRACT: The general conditions necessary for the adsorption mechanism (frequently responsible for a loss of strength in steels and other metals) to become operative are presented and discussed in the light of the most recent advances in the theory of strength. Special attention is paid to structural factors arising as a result of adsorption phenomena, the physical and chemical relationship between the test material and the medium, the crystallographic characteristics of surface compounds, and stress and strain relationships in the lattice.

It has been mentioned [1] that there have been no sufficiently /27* clear concepts presented concerning the particular features of the interatomic relationships which cause changes in the mechanical properties of a solid-state metal acted on by a liquid medium. More categorical statements can also be found in the laterature; their position is that the existing concepts concerning the adsorption mechanism producing a loss of strength in metals (a.l.s. mechanism) do not clarify the physical picture for the effect of the medium, and that the principal details and characteristics of the interaction between the medium and the deformable metal are not explained [2]. Therefore, further discussions of the theoretical principles of the a.l.s. mechanism are very urgent. Based on an analysis of experimental data, P. A. Rebinder and P. V. Pertsov [3] first formulated the following position: the a.l.s. mechanism arises for that combination of solid and liquid metals in which these metals can form a simple eutectic system (without intermetalloids, and with a low reciprocal solubility of the components in the solid state).[1] Subsequent studies have confirmed that, when this condition is satisfied, there is almost always an a.l.s. mechanism; thus, this condition can be considered to be sufficient.

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[1] Obviously, the position of the eutectic point on the constitution diagram can also have certain significance.

† All-Union Economics Correspondence Institute, Moscow

* Numbers in the margin indicate pagination in the foreign text.

However, it is well known that the formation of a eutectic system by two substances is a secondary condition, since it itself depends on a combination of several physico-chemical factors; moreover, this condition generally sheds little light on the physical essence of the phenomenon. It is important to determine the primary factors which cause the a.l.s. mechanism during the interaction of two substances, and to explain the physical role of each.

It is not entirely clear whether or not the possibility of formation of a eutectic system is a necessary condition (during the interaction of two metals) for the appearance of the a.l.s. mechanism. It is well known that, during the interaction of metals with organic liquid media [7], this condition cannot be fulfilled. Obviously, the factors which cause the a.l.s. effect for such substances are even more vague than those for the interaction of two metals.

Several advances have been made in a number of studies [1,4-6] /28 toward a further development of the theory. For the case when the entropy term in the Gibbs equation can be disregarded (i.e., at relatively low temperatures), M. I. Chayevskiy suggested that the a.l.s. mechanism depends on the thermal effect (positive or negative) during the mixing of two liquid metals [5]. However, the sign of the thermal effect during the mixing is a no less complicated condition than that for the formation of a eutectic system. Therefore, this factor does not clarify the problem of the *mechanism* for the effect of the liquid metal on the deformed metal. The fact of the heat absorption during the mixing of liquid metals does not characterize the reciprocal solubility of metals in the solid state (does not permit evaluations of the width of the regions of solid solutions in a phase diagram), and it is not an unequivocal indication that a eutectic system will be formed, or that the a.l.s. mechanism will arise. With most simple eutectic systems, a positive energy of mixing of the components is characteristic. At the same time, we know that, in such simple eutectic systems as Ag-Ge, Ag-Si, Al-Ge, Al-Si, Au-Ge, and Au-Si, the energy of mixing is negative. Moreover, we cannot ignore the fact that some eutectic systems (for example, Pb-Sb and Bi-Sn) are close to ideal ones, judging by the heat of mixing. Finally, there are those systems which are characterized by a positive energy of mixing for liquid components, but which are generally not eutectic ones (for example, Bi-Sb), and the a.l.s. mechanism should not occur.

According to the concepts presented, selection of the described criterion as an indication that the a.l.s. mechanism will arise is not valid. (Even for metal systems, not to mention systems in organic liquid media.)

It has been shown [1,6] that the a.l.s. mechanism arises when the interacting metals are not transitional. However, as the authors themselves have noted, this condition cannot be considered sufficient. This involves the crystallographic structure of a solid metal,

although the role of this factor has not been clarified.

As we all know, a short-range order in the arrangement of the atoms is also maintained in a liquid metal; therefore, we must also take into account the structure of the liquid metal. We have suggested that a favorable combination of the structures of both metals plays an important role in the selectivity of the a.l.s. mechanism.

This analysis permits us to formulate the conditions (according to the atomic structure of the interacting substances) necessary for the a.l.s. mechanism. Having determined these conditions, we based our arguments on the following principal position: the interaction between the liquid and solid phases is linked with substantial adhesive bonding between them, as well as with the arising stresses in the crystal lattice of the thin surface layer of the deformed metal, which play a significant role in the a.l.s. mechanism. Such an interaction is possible under the following conditions.

(a) The presence of geometrically conformable, conjugate groups of atoms in the structure of both substances (by this, we mean the structures of both substances in their solid state). If the deformed metal is a single crystal, the corresponding groups of atoms should be in those crystallographic planes which are in contact with the liquid medium.

(b) The differences in the parameters of the conjugate groups /29
of atoms should have certain limits.[2]

(c) There should be a favorable combination of the electron structure of the atoms of the contact substances: the physical interaction of the force fields of the atoms should produce a rather strong attraction between them. This interaction also depends to some extent on the temperatures; therefore, the temperature factor is also an important condition for the arisal of the a.l.s. mechanism.

The magnitude of the stresses arising in the crystal lattice of the deformed substance depends on the difference in the parameters of the conjugate groups of atoms, as well as on the relationship between the adhesion forces and the forces acting within the groups of atoms of the liquid and solid substances. The a.l.s. mechanism can be observed with rather great tensile stresses.

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[2] In a number of cases, the magnitudes of the atomic diameters can be used for a quantitative characteristic of the dimension factor.

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